PROGNOSTIC INDICATORS AFFECTING FUNCTIONAL OUTCOME IN ZONE II FLEXOR TENDON REPAIRS

Dissertation submitted to

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M.Ch BRANCH - III

PLASTIC SURGERY

INSTITUTE OF RESEARCH AND REHABILITATION OF HAND & DEPARTMENT OF PLASTIC SURGERY

STANLEY MEDICAL COLLEGE & HOSPITAL

CHENNAI - 600 001 TAMIL NADU, INDIA.

AUGUST 2009

CERTIFICATE

Dissertation on

Prognostic Indicators Affecting Functional Outcome In Zone II Flexor Tendon Repairs

Certified that this dissertation is a bonafide work of **Dr. N. KANNAN** Post Graduate in M.Ch Plastic Surgery during 2006-2009 at the Institute of Research and Rehabilitation of Hand & Department of Plastic Surgery, Stanley Medical College, Chennai. This study was done under my supervision and guidance.

Prof .T.C.CHANDRAN
Professor and Head
IRRH & DPS
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Stanley Medical College, Chennai – 1
Ethical Committee

CERTIFICATE FOR APPROVAL OF ETHICAL COMMITTEE

To
Dr.N.Kannan, PG in M.ch (Plastic Surgery)
Dear **Dr.N.Kannan, M.ch (Plastic Surgery)**
The Institutional Ethics Committee reviewed and discussed your application for approval of the project entitled

"Prognostic indicators affecting functional Outcome in zone-II flexor tendon repair"

The following members of the ethics committee were present at the meeting held on 24.02.2009 at the Modernised Seminar Hall, Stanley Medical College, Chennai-1 at 12.00Noon

Dr.C.B.Tharani, Director of Pharmacology,
Madras Medical College, Chennai-3 Chairman of the Ethics Committee
Dr.A.Sundaram, Vice-Principal,
Stanley Medical College, Chennai – 1 Member Secretary of the Ethics Committee

Members

Dr. Jayanthi
Prof. of Medical Gastroenterology
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Dr.P.Dhileepan
Prof.of Surgery
Tmt. T. Mary Ramola
Administrative Officer
Thiru. A. Senthil Manoharan
Advocate

We approve the project to be conducted in its presented form.
The Institutional Ethics Committee/Independent Ethics Committee expects to be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent and asks to be provided a copy of the final report.
Yours sincerely,

Member Secretary,
Ethical Committee

STANLEY MEDICAL COLLEGE ★ CHENNAI-600 001. ★
24 FEB 2009

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I would like to thank Professor **T.C.CHANDRAN**, **M.S., M.Ch.,** Prof and Head of the Department, Institute of Research & rehabilitation of hand & Department of Plastic surgery for granting me the opportunity to conduct the study & also guiding me for the study

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I thank all my patients, who allowed me, for the study and also for their unlimited cooperation during Post operative rehabilitation & follow up.

AIM OF THE STUDY

1. To analyse the prognostic indicators, which influence the functional outcome in Zone II Flexor tendon injuries in fingers.

2. To compare the functional outcome based on independent variables, as observed during surgery.

3. To analyse the overall results in Zone II flexor tendon injury based on our protocol.

LITERATURE REVIEW

Tendon Anatomy:

Extrinsic flexor tendons to the fingers are

1) Flexor Digitorum Superficialis (FDS)
2) Flexor Digitorum Profundus (FDP)

Flexor Digitorum Superficialis: (FDS)

FDS Muscle has ulnar and Radial origins.

Ulnar Origin:

Arises from medial epicondyle, ulnar collateral ligament , & coronoid process

Radial Origin:

From oblique line of radius on its anterior proximal surface.

FDS tendon usually arises from a single muscle belly and capable of producing independent digital flexion and inserted into base of middle Phalanx of each finger with two slips.

Flexor Digitorum Profundus: (FDP)

Origin:

Muscle arises from anterior medial ulna, ulnar half of interosseous membrane. FDP tendons to all fingers originate from a common muscle belly and producing simultaneous flexion. FDP tendon to index finger may have an independent muscle belly & action.

Insertion:

FDP tendons are inserted into volar aspect of base of Terminal Phalanx of fingers.

Tendon covering:

Tendons are covered by a loose areolar layer of Paratenon before entering the digital flexor tendon sheath which facilitates gliding & nutrition.

In digits covered by a close ended synovial bursa with a parietal & visceral layer, containing synovia like fluid which Provides Nutrition & Gliding. It extents from Metacarpal Neck to DIP Joint level.

Tendon Components :

70% of tendon composed of type I collagen. Ground substance, Elastin ,Tenocytes, Blood vessels, Nerves & lymphatics make up the remainder of the tendon.

Tendon fibrils undergo cross linkage to form tendon fibers. These fibers are grouped into fasciculi, which then form tendon bundles.

Epitenon is a thin layer on the tendon's outer surface that extends inwards between tendon bundle & Fasciculi to form the endotenon. Mature tenocytes are found within the tendon and epitenon.

Intrinsic vascularity of the tendon runs within the endotenon and parallels the collagen fibers.

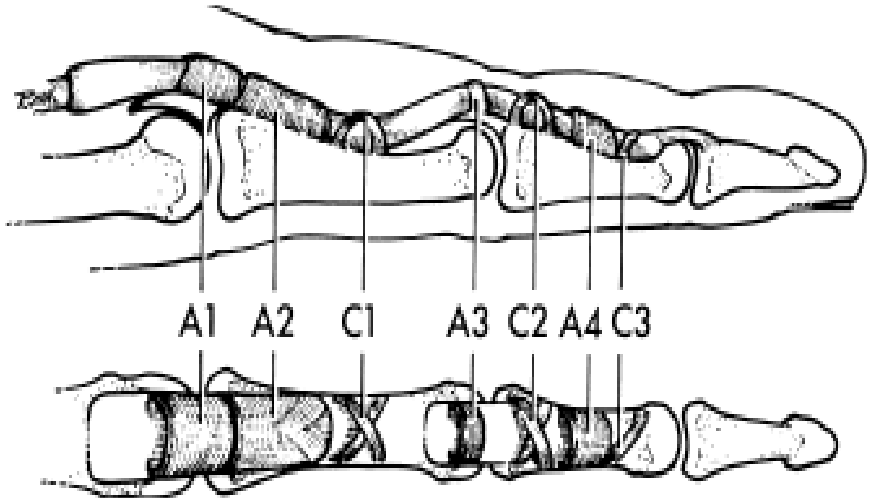
Pulleys:

Pulleys for the flexor tendons consist of

1. Transverse carpal ligament,
2. Palmar aponeurotic pulley, and
3. Digital pulley system.

Digital pulley system:

Five annular & three cruciate pulleys keep flexor tendons closely apposed to the volar surface of phalanges & Joints. This relationship allows a protected environment and smooth surface for the tendons enabling maximal flexion of the joints with minimal tendon excursion.



Digital Pulley System

Annular pulleys are numbered from proximally to distally, and are as follows.

A1, A2,A3, A4, and A5

Odd numbered pulleys namely A1, A3, and A5 originate from the volar plates of MCP, PIP & DIP Joints respectively.

A2 Pulley arises from periosteum at the proximal third of proximal phalanx. A4 pulley arises from periosteum at the middle of the middle phalanx. Annular pulleys are made of thick transversely oriented flbrous bands that are relatively inflexible.

Cruciate pulleys are numbered proximally to distally and are as follows:

C1, C2, and C3,

C1- between A2 & 3 Pulleys

C2-between A3 & A4 Pulleys

C3- between A4 & A5 Pulleys

Cruciate pulleys are thin & flexible, therefore allowing flexion and extension of the semirigid fibrosseous canal. Of these A2 &A4 Pulleys-biomechanically most important.

FLEXOR TENDON ZONES

Flexor Tendon Zones

Verdan is credited with conceptualizing the five flexor tendon zones.

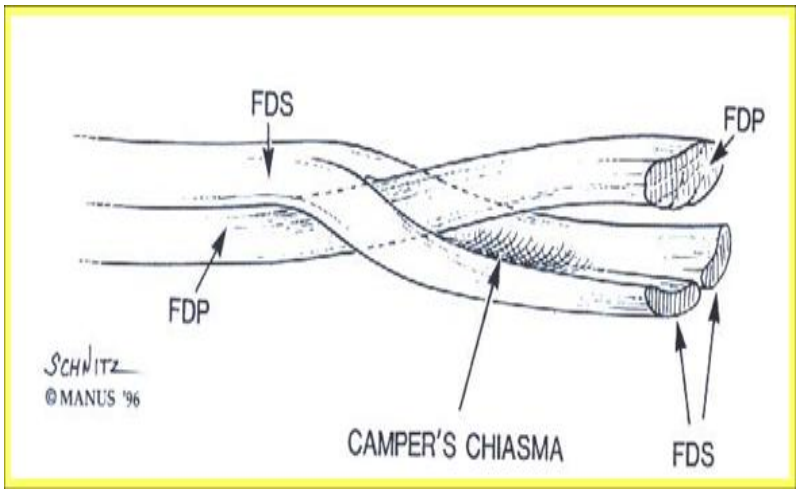
They are:

Zone I: distal to insertion of FDS. Only FDP is present here.

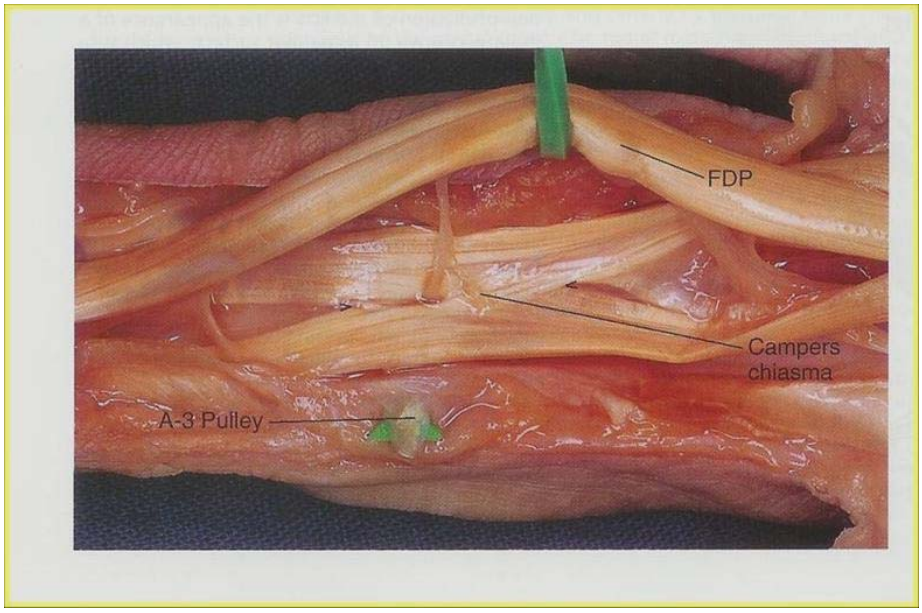
Zone II: extends from FDS insertion to the proximal edge of A1 pulley.

It was termed as “No man’s land” by Bunnell because both FDS & FDP tendons are enclosed within a relatively tight fibro osseous tunnel. FDP

Splits FDS at the ‘Chiasma of Camper’. This close interrelationship predispose to adhesion formation between tendons & surrounding structures.

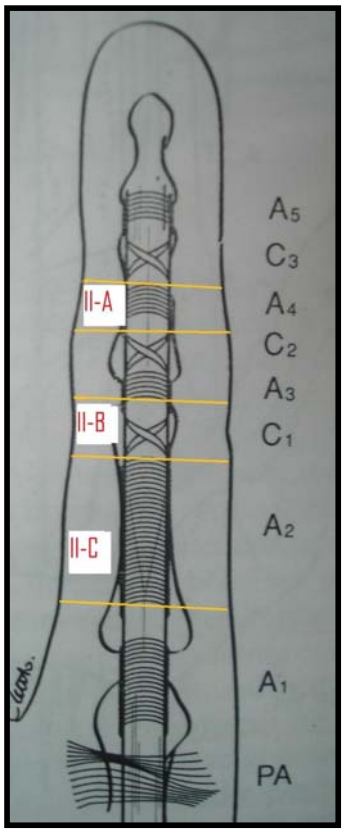


CHIASMA OF CAMPER



CHIASMA OF CAMPER

Subzones in Zone II:



Tang subdivided Zone II into three subzones.

These are

IIA- beneath the A4 Pulley

IIB - beneath the C1 Pulley

II-C - beneath the A2 Pulley

He reported both tendon repairs in IIA and IIB subzones with fewer complications. He also suggested only FPD repair in IIC with fewer complications.

Zone III :

It extends between distal edge of the transverse carpal ligament and the proximal edge of the fibro osseous canal. Because there is no fibrous flexor sheath here, repairs in this region are more favorable.

Zone IV :

It lies deep to Transverse carpal ligament. Narrow space here produces more complications following tendon repair.

Zone V :

Lies proximal to the carpal tunnel in the forearm. Here the tendons are covered by a mobile paratenon and so these is less chance of adhesion formation.

TENDON HEALING & REPAIR

Tendon Nutrition & Vascularity :

Nutritional supply to tendon is bimodal and derived from

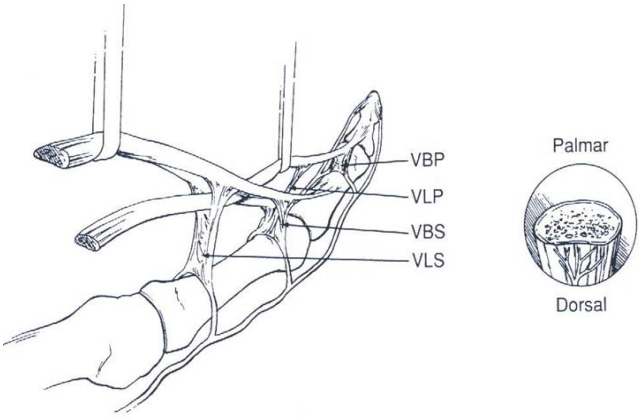
1. Synovial diffusion, and
2. Intrinsic tendon vascularity

   Synovial diffusion may be more important in volar 50% of the tendon & in areas of relative avascularity.

Intrasynovial Tendon Vascularity :

Comprises of

1. Longitudinal dorsal vessels onginating in the palm, the proximal synovial fold.
2. Vincular system from paired digital arteries, and
3. Bone insertions at tendon ends.



Vincular System

Both FDS, FDP tendons have long & short vincula. Variations exist, and the long vinculum to the profundus may be absent. Care must be taken not to damage the vincula during tendon repair.

Over the proximal phalanx, both FDP & FDS tendons are relatively avascular. FDP also has a relatively avascular zone over middle phalanx. These areas lip deep to the major pulleys and are subjected to the greatest compressive forces during flexion.

Tendon Healing :

Flexor tendons heal by way of both

1. Intrinsic tendon mechanisms, and
2. Extrinsic mechanisms

Both healing occur simultaneously, but the relative contributions from each will depend on the type of injury, surgical technique & post operative rehabilitation.

Intrinsic healing occurs within the substance of tendon through resident tenocytes of the epitenon & endotenon, nourished by the intratendinous blood supply and by synovial diffusion.

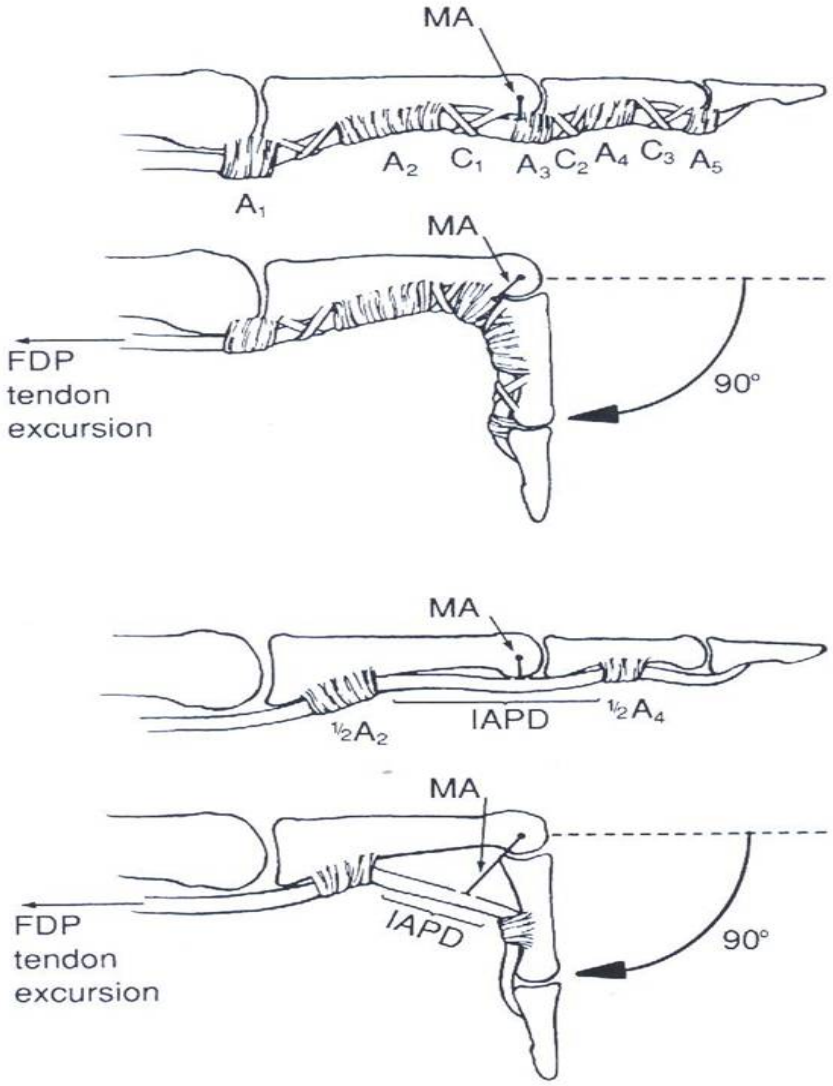
Extrinsic healing originates from cells residing outside the tendon through a sequential process of inflammatory cell activation, revascularization, and fibroblast ingrowth through the damaged flexor sheath. The resulting adhesions provide a route for nourishing blood supply but limit tendon excursion.

Experimentally synovial diffusion appears more important than vincular blood supply for intrinsic healing. But *Amadio* has reported poor clinical results after flexor tendon injuries associated with vincular injury.

Balance between intrinsic healing and extrinsic healing and thus adhesion formation is dependent on the degree of initial injury.

Biomechanics :

A2 & A4 pulleys are biomechanically most important. Pulley efficiency is significantly decreased with loss of the A2 (or) A4 pulley. However disruption of the A1, A3 or A5 (Minor pulleys) has little effect on overall efficiency unless all are divided



Bowstring Effect

Gapping :

Gapping at the site of tendon repair may increase adhesions, disrupt mechanical function (by, in effect, lengthening the tendon) and potentially lead to rupture. In the literature, repair failure is commonly determined by gapping of 2mm (or) more. Gapping after the application of cyclic loads has been the “gold standard” for measurement of the strength of tendon repairs. The load required for tendon repair rupture is the ultimate tensile strength.

Repair strength:

The initial tendon repair strength is proportional to the numbers of suture strands crossing the repair site .Braided polyester is the ideal suture material. It is strong, resists stretch, handles well, and has minimal tissue reactivity. But polypropylene is the suture material commonly used.

Core sutures with 4-0 polypropylene & epitendinous sutures with 6-0 polypropylene are commonly done.

Epitendinous sutures known to smooth out the final repair, to increase repair strength by 10-50%, and to prevent gapping.

After flexor tendon repair there is a decrease in strength of repair with softening of tendon ends and the formation of a gelatinous substance in the initial period. The weakest period occurred 4 to 5 days after the repair

Although there was gradual increase in strength after this, it was not until 19 days that the repair was capable of handling external stress.

After 19 days, the strength of the repair increases and is directly proportional to the stress applied. Because active mobilization protocols may result in higher rupture rates, multistranded tendon suture techniques have been advocated to increase the strength of tendon repairs.

Amadio reported poor clinical results associated with vascular injury.

Tendon healing is divided into three phases;

1. Inflammation (48 to 72 hrs)
2. Fibroblast Proliferation (5 days to 4 weeks)
3. Remodeling

Intrinsic tenocytes and extrinsic flbroblasts migrate to the site of injury for collagen synthesis. Collagen is initially deposited in a random fashion. Ratio of type III to type I collagen is increased. Angiogenesis occurs simultaneously. Remodeling commences when collagen production equals collagen removal. This is usually established by 4 weeks & may last up to 6 months. Tendon strength increases rapidly after 21 days.

Tendon stresses and motion facilitate the reorganization of collagen fibers along the long axis of the tendon and greatly increase the repair strength.

Tension & motion are synergistic in promotion of tendon healing. As a measure of tissue cellularity, total DNA content of the tendon sheath and repair site increases with early motion but does not change with immobilization.

TREATMENT

Timing of Repair:

Tendon repair has been temporally classified into

1. Primary repair –within 12 hrs
2. Delayed primary repair –within 10-14 days (or) before the skin wound has healed.
3. Secondary repair -2 to 4 weeks
4. Late secondary repair–after 4 weeks.

Tendon injury should be repaired as soon as possible. Results of flexor tendon repair were best if done within hours and second best after 10 days. The worst results occurred when repairs were done between 4 and 7 days.

Strickland found that after 4 weeks, muscle fibrosis, tendon contraction and proximal tendon end swelling occurs, that disrupts tendon glide through the pulleys & often preclude direct repair.

Operative:

In zone II lacerations, the sheath and pulleys must be respected, especially the preservation of the annular pulleys. To access the tendon cut ends, synovial sheath windows can be made in the sheath at the C1,C2, (or) C3 pulley levels.

The strong annular pulleys are protected. Partial “venting” (or) release of the A4 pulley to allow tenorrhaphy and of the A2 and A4 pulleys to allow unrestricted tendon glide after tendon repair has been described. The effect

on clinical results is not established, but *in vitro* testing suggests that 25% of either or both of the A2 and A4 pulleys can be released without loss of angular rotation. Little change was seen with upto 75% release.

Flexor Tendon Retrieval & Repairs:

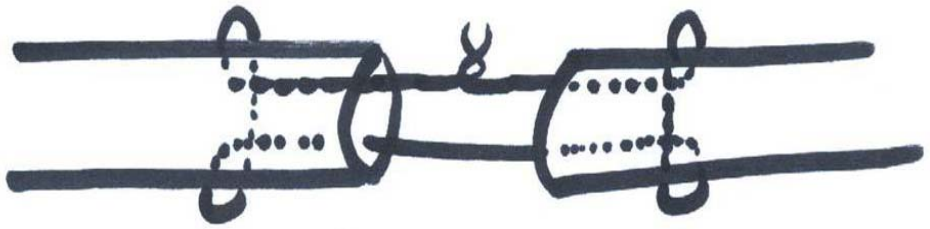
Unfortunately, if the vincula have not restrained the proximal end of the cut tendon, it may have retracted into the palm (or) more proximally. Attempts to recover the proximal end for repair should minimize further trauma to the tendon and synovial sheath. Various techniques have been described to facilitate tendon recovery. If the tendon ends have not retracted far and are visible a skin hook (or) tendon retriever may be used. Suction catheters and endoscopic retrieval have been used. Flexing the wrist and fingers while milking the forearm in a proximal to distal direction can be effective. If difficulty is encountered it is preferable to extend the incision proximally to identify the cut end. Then semiflexible tubing (or) silicone rods can be passed from the repair site through the fibro osseous canal and tied to the proximal tendon end which has been located through an incision proximal to A1 pulley. The tube and tendon are then advanced distally to the synovial window for repair. Placing the core Suture in the proximal stump before advancement avoids further manipulation of the proximal tendon at the final repair. A 22 gauge needle passed through the tendon and into the

sheath at a point proximal to the site of the proposed repair to hold the tendon out and to remove the tension before tendon repair.

In addressing zone II lacerations it is essential to maintain the correct anatomic relationship between the FDS & FDP tendons. The two slips of FDS tendon must roll around the side of the FDP tendon, allowing the FDP to pass smoothly through the FDS and to lie superficial to camper chiasma. Failure to recreate this relationship will restrict tendon glide, increase adhesion and limit digital motion.

SUTURE TECHNIQUES

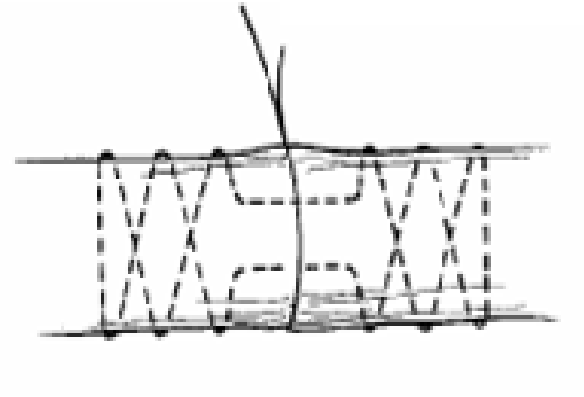
Modified Kessler suture technique is the most commonly used core sutue (McCarthy et al). The core suture is usually 3-0 (or) 4-0 nonabsorbable monofilament (or) braided polyester used in conjunction with an epitendinous 5-0(or) 6-0 nonabsorbable monofilament. These traditional two stranded techniques are generally not strong enough to withstand early active motion.



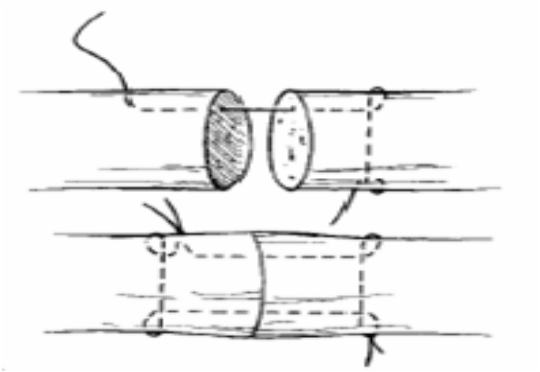
Modified Kessler

Most techniques increase the number of strands crossing the repair site. Two, four, six, and eight stranded techniques have been described. Given the added strength, ability to withstand muscle contraction and minimal increase in difficulty, four stranded technique seem appropriate.

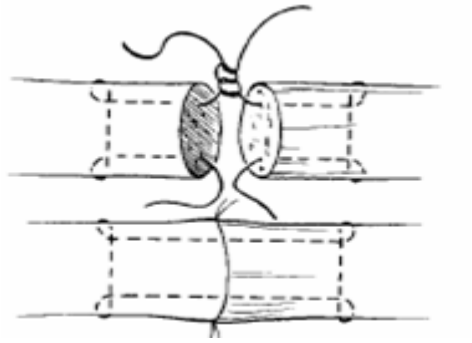
OTHER SUTURE TECHNIQUES



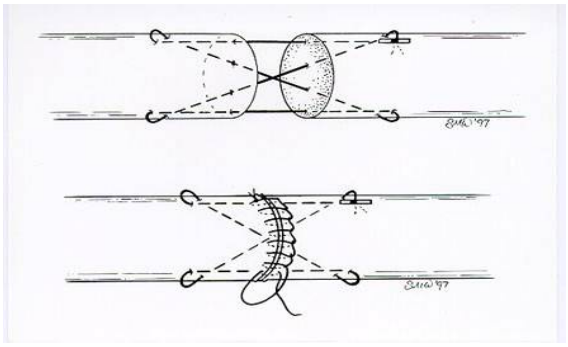
Bunnell's Suture



Kessler Suture



Kessler – Tajima Suture



4 Strand Suture

Tendon sheath:

Lister and others have recommended sheath repair to limit adhesion formation, to facilitate synovial nutrition to help remodel the tendon repair site and to improve tendon sheath biomechanics. However no clear clinical benefit has been shown and repair of the sheath can be technically difficult as well as potentially restricting tendon motion through narrowing. There is no significant difference between sheath excision, repair or grafting with regard to biomechanical, biochemical or morphologic characteristics after tendon repair in dogs.

ASSESSMENT OF FLEXOR TENDON INJURIES

Important points regarding the wound include type of injury - sharp, blunt, avulsion, (or) crush & condition of the soft tissue. Combined FDP and FDS or isolated FDP lacerations are easily diagnosed by observing the affected fingers in relative extension. The natural tenodesis effect on the fingers accompanying wrist flexion and extension will also demonstrate musculotendinous continuity. Blocking the PIP joint and having the patient flex the DIP joint of the same finger tests the FDP tendon. Volar digital lacerations usually injure the FDP before the FDS, but partial or complete FDS injuries must be considered. Isolated FDS lacerations are noted by having the patient try to flex the PIP joint while the remaining fingers are held in extension. Alternatively, during pinch to the thumb tip with the injured finger, if the patient can flex the PIP joint while the DIP joint extends (boutonniere position), the superficialis tendon is at least partially intact. Pain or weakness during resisted flexion may indicate a possible partial tendon laceration and warrant further investigation.

Neurovascular assessment is essential. Digital nerve injuries are repaired or grafted at the time of flexor tendon repair. A dysesthetic digit is more likely to be stiff and less functional.

The presence of associated fractures will affect the treatment, increase the adhesions associated with the flexor tendon repair, and potentially alter the postoperative mobilization.

Imaging :

Both ultrasonography and magnetic resonance imaging are used to diagnose closed rupture, late presentation (or) repeated ruptures after repair. Preoperative localization of retracted tendon ends allows more efficient & less traumatic tendon retrieval. Postoperatively used to distinguish tendon adhesions from tendon rupture.

Ultrasonography:

Non invasive & non ionizing imaging technique that is accurate in assessing flexor tendon integrity and location of cut ends. It is less reliable in the diagnosis of partial tendon laceration & differentiating adhesions from pseudotendon formation.

Ultrasonographers must have musculoskeletal experience and a sound knowledge of hand anatomy because ultrasound examination is operator dependent. Dynamic studies are possible with ultrasound.

Computed Tomography:

Computed tomography (CT) is less expensive than magnetic resonance imaging (MRI) and has been used for the diagnosis of digital pulley rupture. Images are taken during active flexion with demonstration of bowstringing. In the presence of edema, hematoma, and fibrosis, soft tissue differentiation is lost with CT examination. Tendon ruptures are unlikely to be identified. CT also employs ionizing radiation and provides only a static image.

MRI:

It is noninvasive, nonionizing and allows multiplanar imaging. However, it is expensive, is not always available, and does not permit dynamic flexor tendon examination. For hand imaging, specialized coils are preferred. It may be more useful than ultrasound examination for flexor tendon injuries in the wrist and forearm where tissue depth is greater. It can distinguish postoperative adhesions from ruptures with 100% accuracy whereas clinical examination is only 60% accurate. Identification of pulley ruptures with resultant bowstringing is possible. MRI will also locate retracted tendon ends. It may also be useful in partial tendon lacerations and the differentiation of isolated adhesion & Tendon Rupture.

POSTOPERATIVE REHABILITATION

Divided into four groups on the basis of exercises instituted during first 3 to 4 weeks after tendon repair.

1. Immobilization
2. Early passive mobilization
3. Early active extension and passive flexion
4. Early controlled active flexion

Controlled early motion stresses are now accepted to hasten the return of tensile strength, to lessen adhesion formation and repair site deformation and hence to improve tendon excursion. Remodeling of tendon's collagen and the surrounding scar is facilitated with motion. Active mobilization has been shown to provide greater and more reliable tendon movement than Passive mobilization. Early mobilization provides better clinical results than immobilization.

Immobilization :

Rarely is there an indication for immobilization after flexor tendon surgery. Exceptions might include children or adults unable to cooperate with hand therapy, unstable bone repair, and concerns about the effect of tension on microneurovascular repairs. A cast or splint usually holds the wrist in neutral or slight flexion, the MCP joints are significantly flexed, and

the interphalangeal joints are only slightly flexed or extended. The cast or splint is first removed at 3 to 4 weeks to start active and passive movement.

Classic Early Motion Protocols:

The Kleinert and Duran -Houser post tendon repair rehabilitation protocols remain two of the most commonly used methods.

Modified Kleinert:

Uses active extension with passive flexion by a dorsal extension blocking splint with rubber bands running from fingertips (nails) to the volar wrist (or) forearm.

All fingers should be placed in Rubber band traction to ensure added FDP protection and to promote better tendon excursion. Including all fingers decreases the risk of PIP contracture through more efficient action of the extensor digitorum communis.

After 3-4 weeks, the dorsal splint is removed but the rubber bands are maintained and attached to a volar wrist cuff. Gentle active flexion may be started around 4 weeks. At 6 weeks, place and hold exercises and blocking exercises commenced. The original Kleinert splint has been modified with a palmar bar to obtain better interphalangeal joint flexion.

Duran Houser:

It relies on independent controlled passive motions of the digital articulations without the use of rubber bands. The proposed benefits include improved protection between periods of exercise, greater differential glide and prevention of PIP flexion contractures.

Washington regimen is a combination of the Kleinert, Duran - Houser & Palmar bar.

Early Controlled Active Flexion:

Silfverskiöld, using metal markers found that active motion appears to increase tendon excursion over passive motion. But how much force is applied with “light” active motion or place and hold exercises is not well defined and difficult to measure.

Strickland has shown that flexor tendon repairs with four (or) more strands and a strong epitendinous suture should theoretically tolerate light active digital flexion with the wrist in the extended position during the entire period of healing.

COMPLICATIONS

Complications associated with tendon repair divided in to early & late categories.

Early complications include infections, wound healing problems, tendon rupture, pulley rupture & poor tendon glide in tendon sheath.

Late complication include tendon repair ruptures, tendon adhesions, joint contractures, decreased flexion strength, pulley dysfunction with resultant bowstringing.

Adhesions are the most common problem. It occurs in 20-40% after flexor tendon repair.

Rupture rates after flexor tendon repair range from 0-9% for classic protocols and 0-46% for active motion protocols. Ruptures usually occur around day 10, but may occur as late as 6 to 7 weeks after repair.

TREATMENT OUTCOMES

Functional grading systems after flexor tendon repairs that are used in the literature include those proposed by the

1) American society for surgery of the hand
2) Grossman system II
3) Louisville classification system
4) Buck Gramcko's classification system
5) Original and adjusted classification systems of Strickland '

Agreement between the systems is only fair

The American society for surgery of the hand recommends that total active motion (TAM) be used to evaluate the results of flexor tendon surgery. The TAM is calculated for each finger by subtracting the total loss of active extension or hyperextension from the total active flexion. Passive motion is also determined. The calculation involves all three finger joints and averages between 260 and 270 degrees, depending on the finger (MCP,80 degrees ; PIP , 110 degrees DIP , 70 degrees).

The Calculation Is

TAM = (DIP +PIP +MCP) Flexion - extension loss

(DIP+PIP+MCP),

- TAM - Total Active Motion
- DIP - Distal interphalangeal joint.
- PIP - Proximal Interphalangeal joint
- MCP - Metacarpophalangeal joint.

Any hyperextension is also subtracted. The result is compared with preoperative (or) non injured contralateral digit TAM and expressed as a percentage.

On the basis of this comparison the results are classified as follows.

Excellent	-	TAM same as normal side
Good	-	TAM more than 75% of normal side
Fair	-	TAM more than 50% to 74% of normal side
Poor	-	TAM less than 50% of normal side
Worse	-	TAM worse than before surgery

The classification lacks numerical definition for the excellent category and cannot be used for clinical or statistical comparison.

Strickland and Glogovac use a similar calculation but do not include the MCP joint.

$$\text{Percentage of TAM} = \frac{\text{(PIP + DIP) flexion - (PIP +DIP) extension lag}}{177} \times 100$$

Proponents believe that MCP movement is usually normal and can contribute at least 30% of the TAM, thus falsely inflating results. However others believe that inclusion of the MCP joint is important to the functional outcome and that its function is not always normal after flexor tendon injury.

A normal TAM of 177 degrees (100 degrees for the PIP joint and 75 degrees for the DIP joint), is used for comparison.

Results are classified in their adjusted system as follows:

Excellent - 75% -100%

Good - 50%-to 74%

Fair - 25% to 49%

Poor - Less than 25%

The categories in the original system are more strict:

Excellent - 85% to 100%

Good - 70% to 84%

Fair - 50% to 70%

Poor - less than 50%

The Buck Gramcko and the Louisville systems divide results into categorical data and thus decrease their statistical power.

Average flexor tendon repair results taken from the literature

Rehabilitation	**Combined excellent / Good**	**Excellent**	**Good**
Immobilization	20%		
Kleinert	64%	44%	20%
Palmar bar	88%	71%	17%
Duran	69%	53%	16%
Washington	81%	66%	15%
Active Mobilization	82%	58%	24%

FLEXOR TENDON REPAIR –ZONE –II

PROF .T.C.CHANDRAN'S UNIT

Name: P.S.No:

Age: Sex:

Date of injury: Date of surgery:

Address:

Tel no:

Mode of injury:- industrial / Household /RTA:

Nature of injury: Crush/Incised/ Slicing /Avulsion.

PRE - OPERATIVE

WOUND CONTAMINATED: - Yes /No

SKIN: No loss/Skin loss Present

TENDON:

SUB ZONES: II-A/II-B/II-C

INJURY: Both tendons /FDP alone /FDS alone

FDS –Chiasma/ Proximal/ distal

FDS –Both slips / One slip

TENDON CUT ENDS: Clean/ Crushed

VINCULUM: Intact /Injured:

FFS INJURY: Extent of injury

INJURED PULLEYS: (Percentage):

DIGITAL NERVE INJURY: Injured /Not injured

: Single /Both

DIGITAL VESSEL INJURY: intact /Injured

One /Both

BONE: Fracture without bone loss / with bone loss

PER OPERATIVE

INCISION: No extension /Zig zag /Neutral line extension /Skin crease (palmar crease)

TENDON:

Tendon ends: Found in wound/Retracted

Method of retrieval:

Method of suture: Modified Kessler /4 Strand

Epitendinous suture-Done /Not done

SUTURE MATERIAL

Core suture

Epitendinous suture:

FFS: Repaired / not repaired

A2 and A4 Pulleys - Venting done / not done

- Extent

NERVE: Repaired /Not

VESSEL ANASTAMOSIS: Done / not done

BONE FIXATION: done /not done

POST OPERATIVE

At 10^{th} day WOUND –Healed /Not healed

REHABILITATION PROTOCOL

IMMOBILISATION-3 WEEKS

PASSSIVE FLEXION & ACTIVE EXTENSION WITH DORSAL BLOCK

IMMOBILISATION & ULTRASOUND

MATERIALS AND METHODS

A Prospective Study was conducted during the two year period at our institute between November 2006 to October 2008.

21 patients with 28 zone II flexor tendon injuries who presented to us within 24 hrs since injury & repaired primarily were studied.

All are male patients with following age distribution.

10-20 yrs -2 patients

20-30 yrs - 11 patients

30-40 yrs - 6 Patients

More than - 40 yrs – 2 patients

Selection Criteria:

Inclusion criteria:

All zone II flexor tendon injuries in fingers, who presented to our department within 24hrs since injury and repaired primarily were included in our study.

ZONE II INJURIES

Index Finger -FDP&FDS Injury

Index Finger - On Flexion

Little Finger
Both Tendon Injury

Little Finger Injury
On Flexion

Index & Mid Finger
Both Tendon Injury

Little Finger
Both Tendon Injury

Exclusion Criteria:

Patients with other associated injuries which may affect rehabilitation and who presented with soft tissue injury with skin loss, tendon loss and fracture of phalanges were excluded. Patients who did not comply with the rehabilitation protocol were also excluded.

Surgical Protocol:

We repaired both flexor digitorum profundus and flexor digitorum superficialis tendons, if both were injured.

Core suture done with 4-0 polypropylene using modified Kessler suture technique and the sutures are taken 7.5mm to 10mm from cut end of the tendon on either side. Epitendinous suture done with 6-0 prolene continuous sutures.

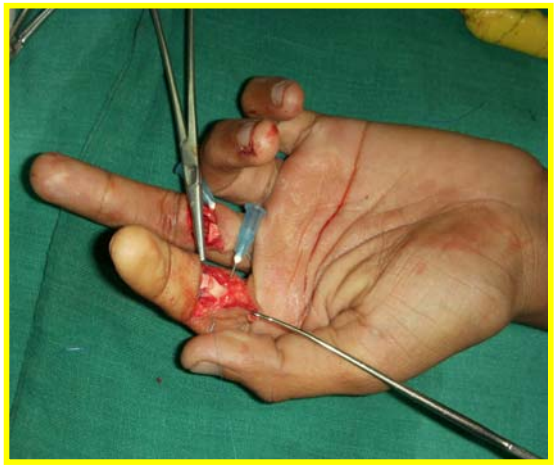
We preserved A_2 & A_4 pulleys and if more exposure was needed upto 50% venting was done for access & to ensure smooth gliding of the sutured tendons.

If the cut end of tendons (proximal end) lie close to the wound, tendons retrieved by flexing the wrist and fingers while milking the forearm in a proximal to distal direction.

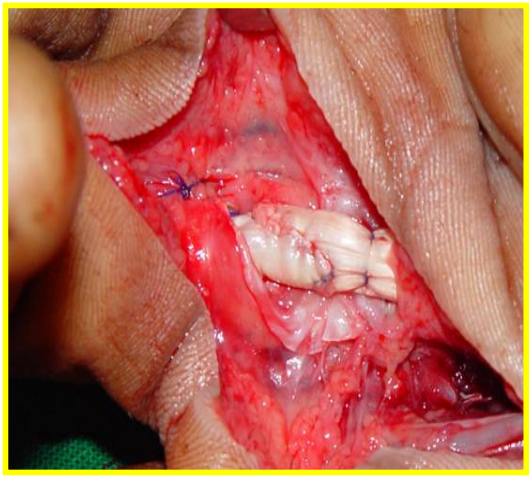
PER OPERATIVE

Tendon Retrieval

Tendon Retrieval - Four Finger Injury



Tendon Repair



After Tendon Repair

PER OPERATIVE

After Repair

After Repair - Index and Mid Fingers

If the proximal tendon ends could not be retrieved by the above method, a transverse skin crease incision in the distal palmar crease proximal to A1 pulley was made & tendons retrieved. Then a suction catheter /Scalp vein set tube was inserted from the wound into the proximal incision and tendons were anchored to the tube & retrieved into the wound.

By transfixing the proximal tendon end with a 22” needle, the retraction of the tendon was prevented and also facilitating tension free repair.

POST OPERATIVE REHABILITATION PROTOCOL

Since we used two stranded (Modified Kessler Suture Technique) core suture, we followed the protocol of immobilization & pulsed ultrasound therapy. We compared our results with results of Kleinert & early active motion protocols mentioned in literature. In most of the studies, they used four stranded technique for core sutures, to facilitate early active motion.

Post operatively hand is immobilized in dorsal POP splint for 3 weeks. Pulsed ultrasound therapy was started on day 7, and continued upto 8 weeks.

Ultrasound Therapy:

It is based on piezo electric effect. It produces micro streaming which has an effect in tendon healing. Similarities exist between early mobilization and ultrasound therapy. Safe and early application of ultrasound in tendon healing had been proved in many animal studies.

We used Pulsed ultrasound of 1 Mhz frequency and administered for 5 minutes daily and 6 days a week.

Post operative days	Intensity of ultrasound
7-14 days	0.7 watt /Cm^2
14-21 days	1 watt /Cm^2
3 weeks – 6 weeks	1.5 watt /Cm^2
6 weeks – 8 weeks	2 watt /Cm^2

After 3 weeks active & guarded passive mobilization was started under supervision of a physiotherapist.

After 6 weeks resisted exercises were started.

Result were analyzed after 8 weeks.

ULTRASOUND THERAPY

Post Operative Assessment :

Analyzed using modified Strickland criteria

$$\text{Percentage of TAM} = \frac{\text{(PIP + DIP) flexion - (PIP +DIP) extension lag}}{177} \times 100$$

Grading

75 -100 % -Excellent

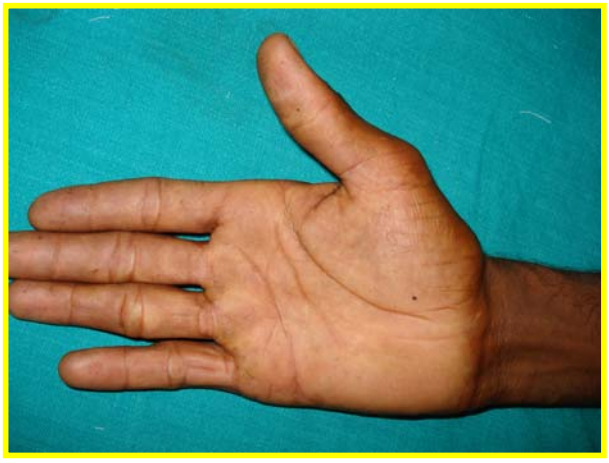
50 -74% -Good

25 -49% -fair

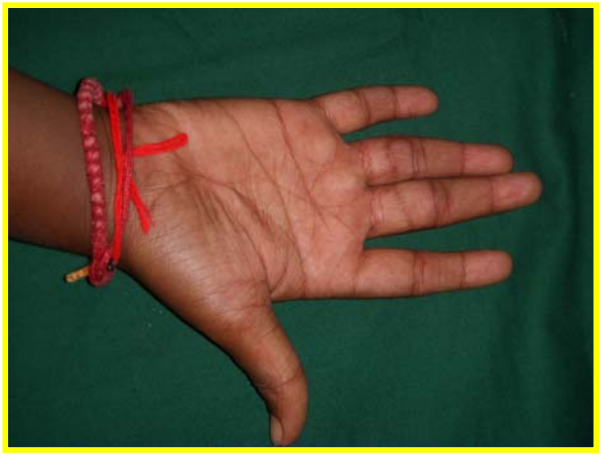
Less than 25% - poor

- PIP – Proximal intephalangeal joint
- DIP – Distal intephalangeal joint

POST OPERATIVE ASSESSMENT



8 Weeks Post Repair –Little Finger



After 10 Weeks - Mid & Ring Fingers

After 8 Weeks - Mid Finger FDP - Not Acting

Ultrasound & MRI (Diagnostic):

High frequency 17 Mhz musculoskeletal ultrasound done in selected cases to find out.

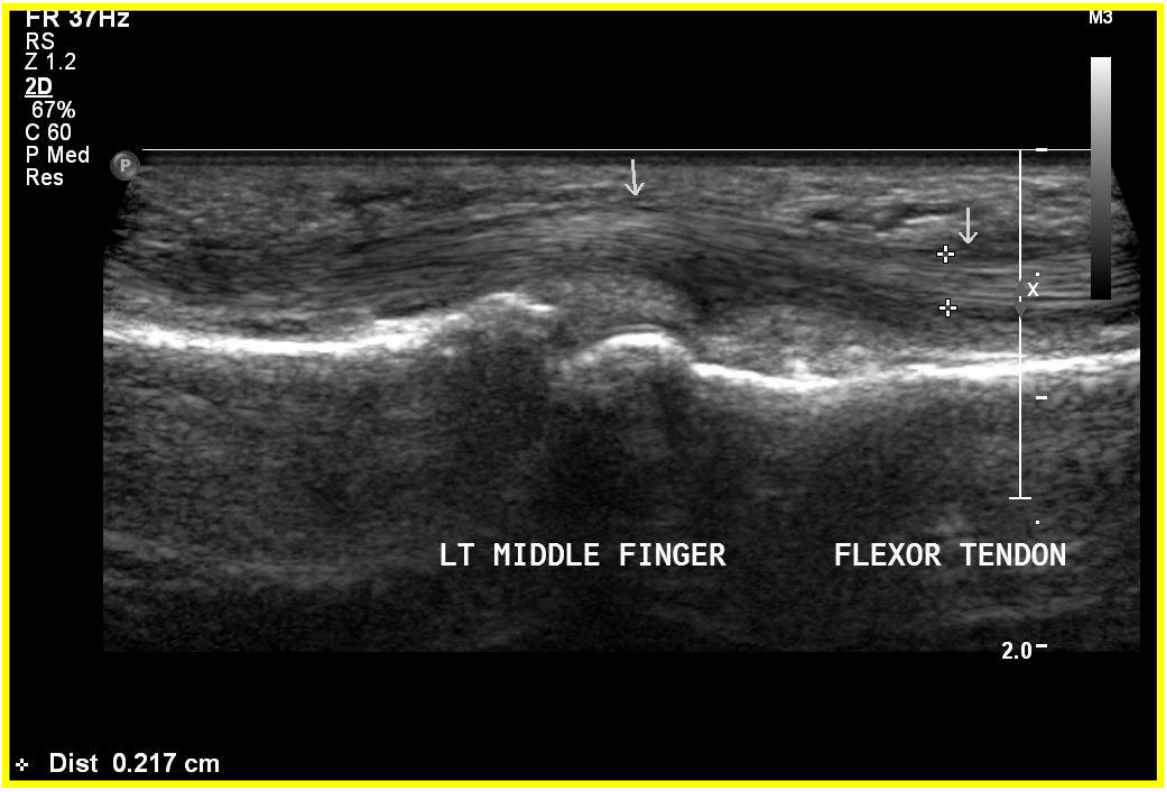
-Continuity of tendons.

-Thinning of tendons.

-Adhesions with tendons and surrounding tissues.

-Gliding of tendons (dynamic assessment).

MRI was done in few cases when tendon rupture was suspected.



Ultrasound of Flexor Tendons - Post Repair

FACTORS ANALYSED

1. Fibrous flexor sheath repair:

We repaired fibrous flexor sheath in few patients and not repaired in others. We compared the functional results of either group.

2. Proximal cut end of tendons :

If the proximal cut end of the tendon is retracted into the palm, tendons are retrieved into the wound as mentioned in the surgical protocol. The functional results are compared with other patients in whom the tendons were present in the wound itself.

3. Injury to vincula:

We recorded the injury to vincula and analyzed the vincula injured group with uninjured group and compared the results.

4. Injury in subzones IIA , IIB, (or) IIC:

Results of injury in subzones of zone II are also analysed and compared.

OBSERVATION AND RESULTS

Functional Results

Excellent - 36% (10)

Good - 43% (12)

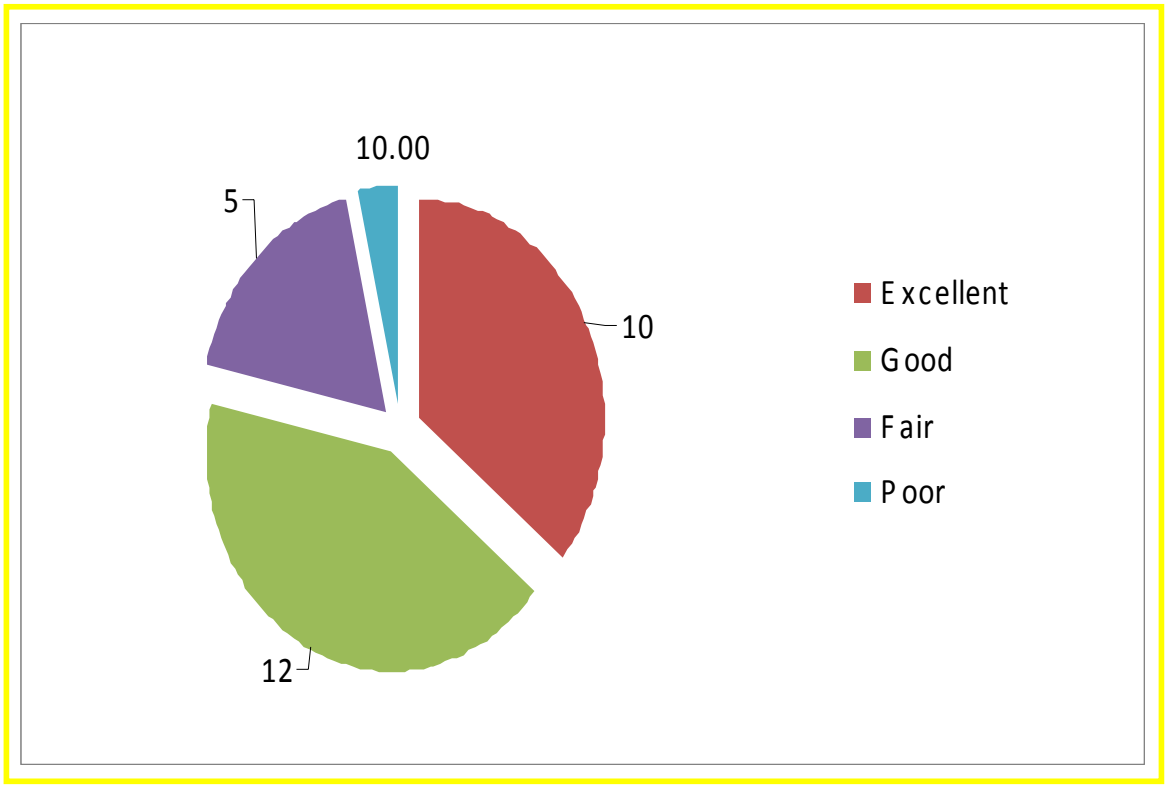
Fair - 17% (5)

Poor - 4% (1)

Out of the 28 fingers we have studied good & excellent results are achieved in 79% of cases. Fair result in 17% of cases.

Tendon adhesions were found in 14% of the patients.

Tendon rupture was found in one patient (3.5%).

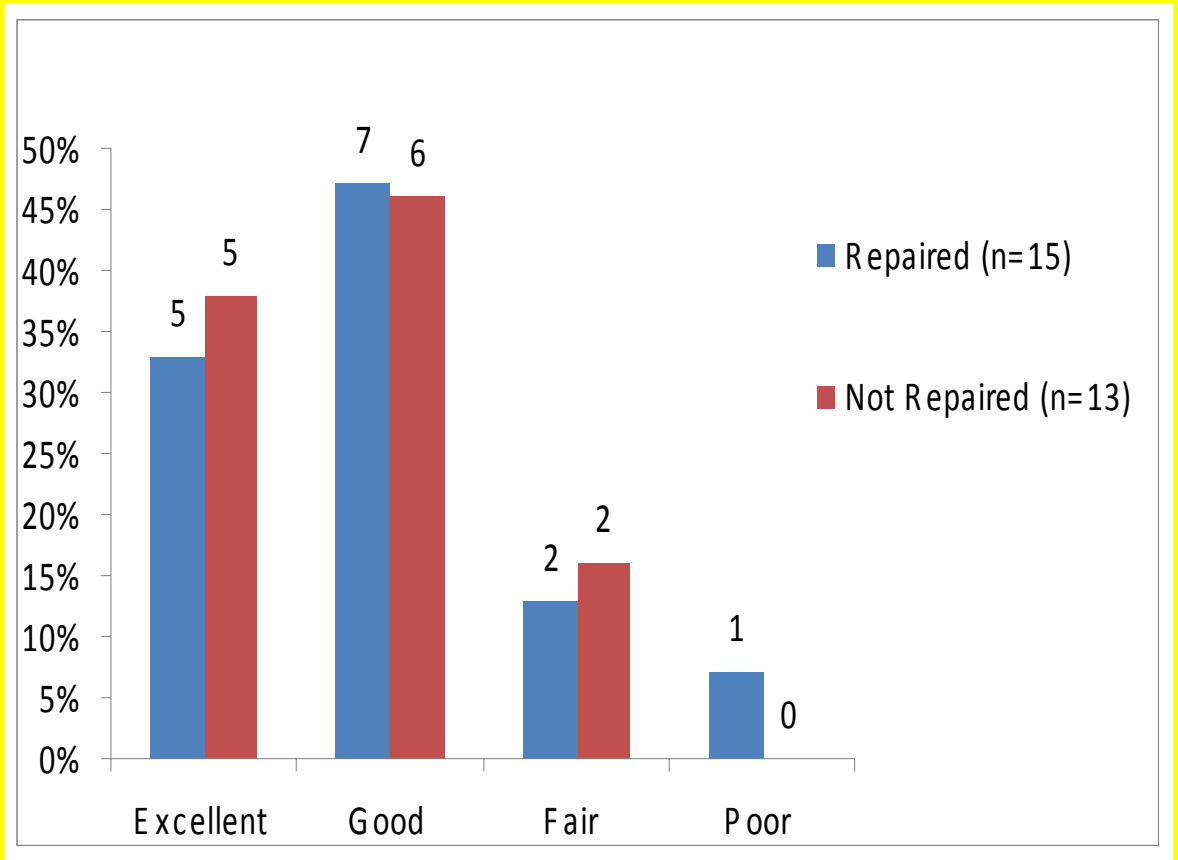


FIBROUS FLEXOR SHEATH REPAIR

	Excellent	Good	Fair	Poor
Repaired (15)	33% (5)	47% (7)	13% (2)	7% (1)
Not Repaired (13)	38% (5)	46% (6)	16% (2)	-

In the FFS repaired group combined excellent and good results were obtained in 80% of patients.

Whereas in FFS nonrepaired group, combined excellent and good results were obtained in 84% of patients.

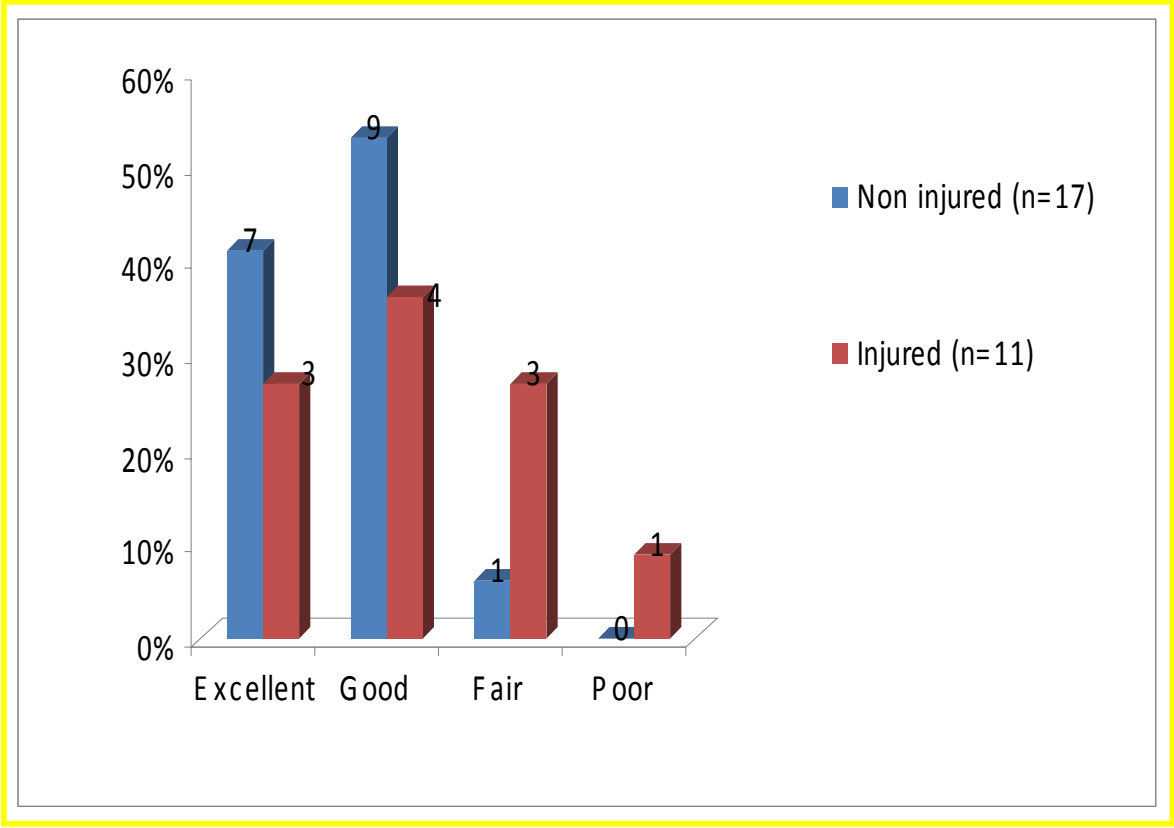


INJURY TO VINCULA

	Excellent	Good	Fair	Poor
Non injured (n=17)	41% (7)	53% (9)	6% (1)	-
Injured (n=11)	27% (3)	36% (4)	27% (3)	9% (1)

If vincula were not injured excellent and good results were obtained in 94% of patients.

If vincula were injured only 63% of combined excellent and good results were obtained.

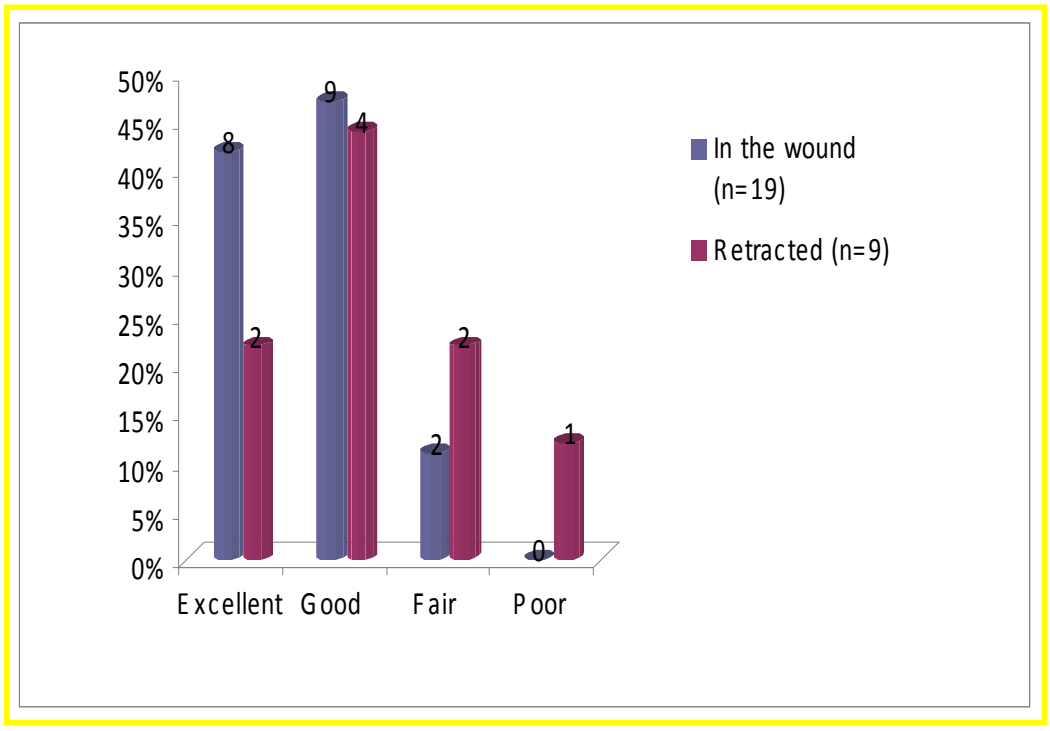


TENDON RETRIEVAL

	Excellent	Good	Fair	Poor
In the wound (19)	42% (8)	47% (9)	11% (2)	-
Retracted (9)	22% (2)	44% (4)	22% (2)	12% (1)

If the tendons were not retracted and found in the wound itself combined excellent and good results obtained in 89% of patients.

If the tendons had retracted into palm, excellent and good results are obtained in only 66% of patients.

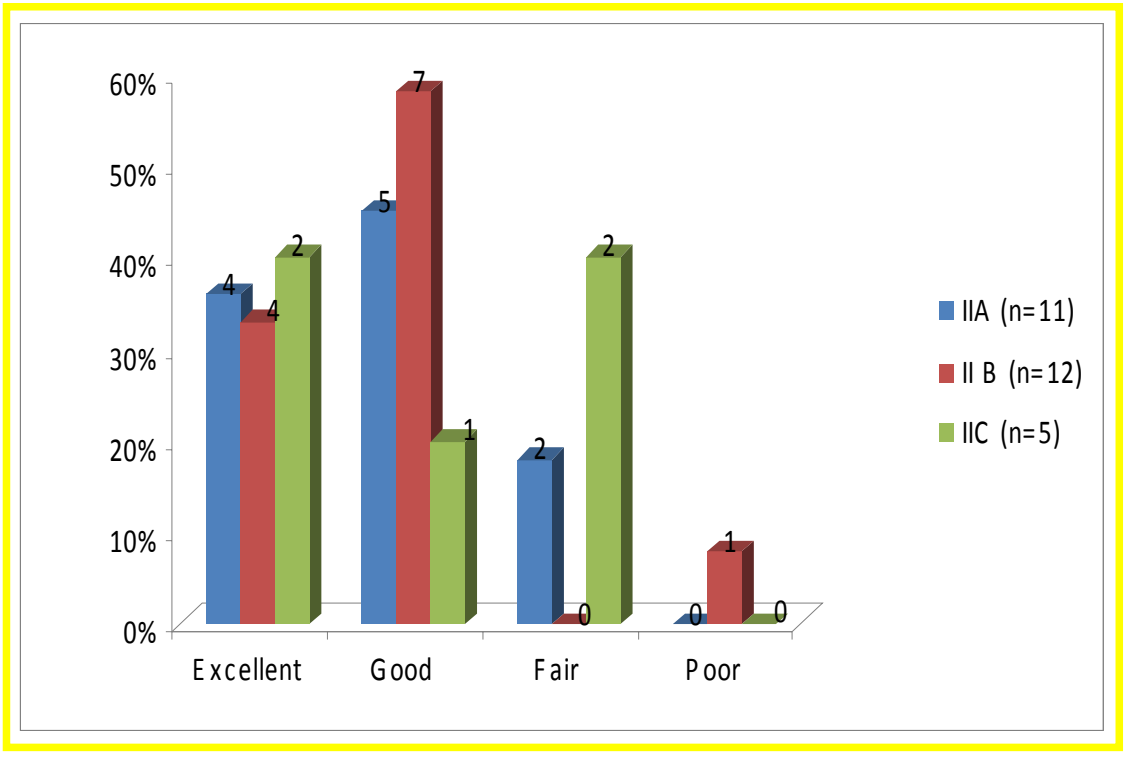


INJURY IN SUB ZONES

	Excellent	Good	Fair	Poor
IIA (n=11)	36% (4)	45% (5)	18% (2)	-
II B (n=12)	33% (4)	58% (7)	-	8% (1)
IIC (n=5)	40% (2)	20% (1)	40% (2)	-

Zone II A - Good and excellent results were obtained in 81% of patients, where as in II B in was 91%.

In zone IIC, 60% of excellent and good results were obtained.



Complications:

In our study we encountered the following complications

Tendon rupture – 1 patient

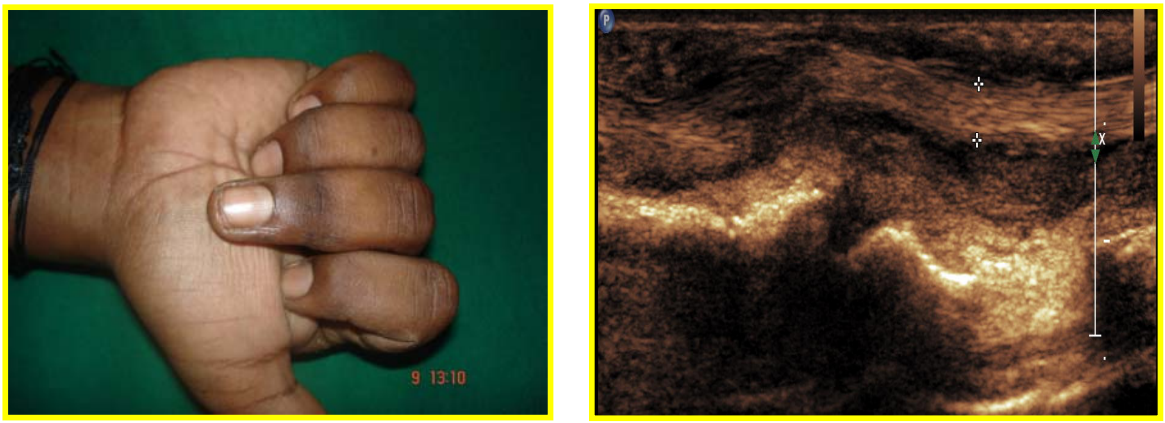
Tendon adhesions – 4 patients.

Tendon rupture occurred in one of our patients, who showed poor results according modified Strickland criteria. It was confirmed using musculoskeletal ultrasound.

Adhesions:

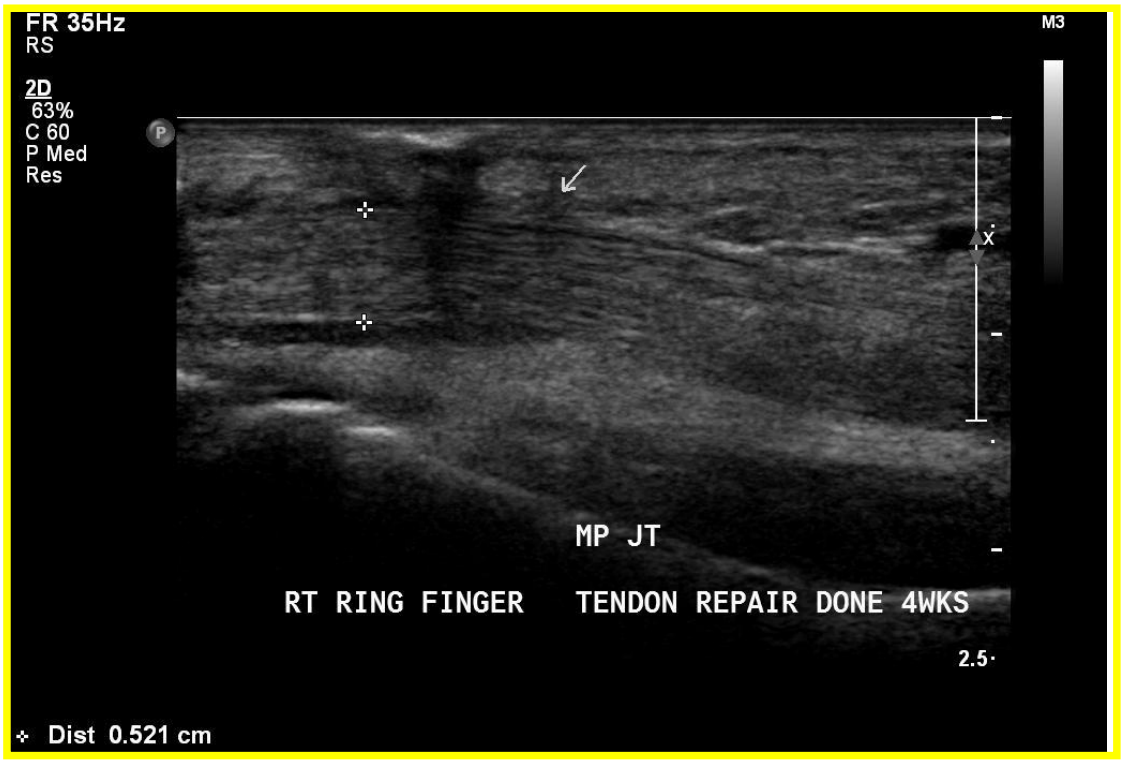
We encountered adhesions in 4 of our patients in the post operative period, who had fair results according to modified Strickland criteria.

Dynamic ultrasound of the patients confirmed the findings.



Tendon Adhesion

ULTRASOUND (DIAGNOSTIC)



Tendon Gapping at Four Weeks

Tendon Ruputre at Eight Weeks

DISCUSSION

Various clinical studies in the literature have shown combined excellent and good results of around 80% in Kleinert and active mobilization protocols. Most of the authors used 4 strand suture techniques. But we used the 2 strand modified Kessler suture technique with postoperative immobilization and ultrasound therapy as our protocol. In our study we obtained excellent and good result in 79% of patients.

Postoperative tendon adhesion is the most common complication, which is around 20-40% in various studies. In our study it is 14%.

Tendon rupture rate range from 0-9 % in classic protocols to 0-46% for active mobilization protocols. In our study it is 3.5%. So the postoperative ultrasound therapy has effects in preventing tendon adhesions and also promotes tendon healing.

We have also analyzed independent variables using the same protocol. Although there is controversy regarding FFS Repair and functional outcome, our study shows there is not much difference in either of the groups.

Injury to vinculae and retraction of proximal cut end of tendon into palm and retrieval of tendon, have adverse effects in functional outcome.

Good and excellent results were obtained in only 66% of patients. Whenever vincula was not injured excellent and good results were obtained in 89% of patients.

Tang subdivided zone II into three zones and suggested both tendon repair in IIA,and IIB . He suggested single tendon (FDP) repair in IIC region because of complex anatomy and relative avascularity

In our study, although we have limited number of patients in Zone IIC injury, we are able to achieve 60% of excellent and good results with both tendon repair.

Post operatively at 8 weeks we assessed the anatomical status of the repaired tendon using 17 MHz ultrasound which demonstrated the anatomical continuity of tendon, gapping of tendons as well as rupture of repaired ends. Another big advantage of ultrasound is dynamic assessment.

Four of our patients who had tendon adhesions were treated by tenolysis. In one case of tendon rupture, reexploration and secondary repair was done.

CONCLUSION

1. Fibrous flexor sheath repair does not influence functional outcome.

2. Injury to vincula and retraction of proximal cut end of tendon into palm adversely affects the results.

3. Repair of both tendons even in Zone IIC – have Reasonable functional results.

4. High frequency musculoskeletal ultrasound is a better investigation in the postoperative followup to find out tendon adhesions and rupture and most importantly dynamic assessment.

5. The protocol of immobilization and pulsed ultrasound therapy have comparable functional results and less complications when compared with early motion protocols.

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